Key points

- Observational and high-resolution (1/4°) model data explore the impact and seasonality of submesoscale processes in the upper 1 km of the open ocean.
- 5 ocean gliders were deployed in a small region of the northeast Atlantic Ocean, in prep.
- Potential energy (PE) increases in winter at depths much greater than the mixed layer depth (MLD), suggesting exchange of water across the base of the mixed layer during winter.
- Slopes of PE and space structure function are \( \lambda \), consistent with a spectral slope of 4.
- Weak stratification across the base of the mixed layer in winter leads to higher potential for subduction of water and biological export.

Study Site

Structure Functions

Structure functions are a complementary approach to Fourier power spectra and are useful for simultaneous glider deployments.

\[ \Theta(b) = \frac{b^2}{b^2 + \sigma^2_{\text{ref}}} \]

Structure functions slope \( \lambda \) is related to a spectral slope \( k^{-\lambda} \).

Oxygen variability varies with depth but not with spatial scale.

Implications for biological export

BIOLOGICAL EXPORT THROUGH SUBMESOSCALE INSTABILITIES

Export production through submesoscale instabilities requires these instabilities to be co-located with biological material (e.g., particulate organic carbon, POC) in the surface ocean. The two major instabilities considered here are symmetric instability (SI) and baroclinic mixed layer instability (MLI). SI acts to the maximum depth \( h \) such that

\[ \int_0^h PV \text{d}z < 0. \]

For PV = \( f(x,v_b - v_{g1} + v_{g2}) \), where glider data, we approximate \( PV \text{d}z = (f + v_{g1} - v_{g2})/f \). Vertical velocity associated with MLI can be estimated from an overturning streamfunction \( \psi \)

The normalized function \( \mu_r \) represents the strength of the overturning throughout the mixed layer and is set to 1 giving a maximum \( \mu_r \).

Figure 1: Glider (solid) and model (dotted) region.

Figure 2: (a) Sample span along a given latitude from a model snapshot. (b) Structure function of the data (black). Blue points mark median (green line). Interequator range (blue rectangle) and blue envelope (green line) (c) Comparison of the structure function \( \Theta(b) \) (black) with a Fourier power spectrum for the same dataset (grey). Effective resolution is shown as \( \Delta x \), where \( \Delta x = 1.5 \) km. (d) Black lines denote time when each glider was deployed.

Figure 3: (a) MLD for the gliders (black) and model (grey), defined as \( z_{\text{MLD}} = \frac{1}{\rho_0} \rho_0' \) at 10 m depth. (b) \( N^2 = 0 \) at the base of the mixed layer.

Figure 4: Space (a,b) and potential energy PE \( = \int u^2 \text{d}x \) at 200m in (a,c) and 800m (b,d) depth from a model snapshot on 01 January 2013. Black box in each panel gives the size of the glider deployment region. Space is plotted along constant potential density surfaces corresponding to each depth \( (\sigma = 27.04, 27.45 \text{ kg/m}^3) \), respectively, to negate effects of internal waves.

Figure 5: Structure functions during winter measurements (1 Jan to 10 Nov) for potential energy \( \psi_H \) (a-d) and PE \( \psi_V \) (e-h). Top panel: from gliders (black) and model (grey). Bottom 3 log-log slopes \( (\lambda) \) for each depth are shown on the right (a,c,e,g).

Figure 6: Space (a,b) and potential energy PE \( = \int u^2 \text{d}x \) at 200m in (ac) and 800m (b,d) depth from a model snapshot on 01 September 2012. Black box in each panel gives the size of the glider deployment region. Space is plotted along constant potential density surfaces corresponding to each depth \( (\sigma = 27.11, 27.43 \text{ kg/m}^3) \), respectively, to negate effects of internal waves.

Figure 7: Space (a,b) and potential energy PE \( = \int u^2 \text{d}x \) at 200m in (ac) and 800m (b,d) depth from a model snapshot on 01 September 2012. Black box in each panel gives the size of the glider deployment region. Space is plotted along constant potential density surfaces corresponding to each depth \( (\sigma = 27.04, 27.45 \text{ kg/m}^3) \), respectively, to negate effects of internal waves.

Figure 8: Space (a,b) and potential energy PE \( = \int u^2 \text{d}x \) at 200m in (ac) and 800m (b,d) depth from a model snapshot on 01 September 2012. Black box in each panel gives the size of the glider deployment region. Space is plotted along constant potential density surfaces corresponding to each depth \( (\sigma = 27.11, 27.43 \text{ kg/m}^3) \), respectively, to negate effects of internal waves.

Figure 9: (a) PARTICULATE BACKSCATTER (b,c) as an average over the upper 25 m (green) and integrated over the upper 500 m (red) from glider measurements. (b) MLD from gliders (black) and model (grey). Depth at which symmetric instability (SI) and baroclinic mixed layer instability (grey). (c) Derived absolute value of vertical velocities associated with mixed layer baroclinic instability from the glider data (black) and model (grey).

Figure 10: (a) PARTICULATE BACKSCATTER (b,c) as an average over the upper 25 m (green) and integrated over the upper 500 m (red) from glider measurements. (b) MLD from gliders (black) and model (grey). Depth at which symmetric instability (SI) and baroclinic mixed layer instability (grey). (c) Derived absolute value of vertical velocities associated with mixed layer baroclinic instability from the glider data (black) and model (grey).

Figure 11: PARTICULATE BACKSCATTER (b,c) as an average over the upper 25 m (green) and integrated over the upper 500 m (red) from glider measurements. (b) MLD from gliders (black) and model (grey). Depth at which symmetric instability (SI) and baroclinic mixed layer instability (grey). (c) Derived absolute value of vertical velocities associated with mixed layer baroclinic instability from the glider data (black) and model (grey).